# THE ODYSSEY OF VOYAGER AND MAGELLAN

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The Voyager and Magellan spacecraft have provided an unprecedented set of discoveries in space during the past 15 years. Voyager had its origins in the "Outer Planets Grand Tour" to the outer solar system but was scaled down to a mission to Jupiter and Saturn with an option to proceed on to Uranus and Neptune. These were indeed accomplished with two Voyager spacecraft launched in the summer of 1977 leading to the final planetary encounter at Neptune in 1989. Magellan had its origins in a more comprehensive program to Venus and ironically was in a planning and development stage during most of the Voyager flight odyssey to the outer planets between 1977 and the Magellan launch in May of 1989. The Voyager mission was a once-in-a-lifetime opportunity since the mission needed planetary gravity assists to acquire sufficient velocity to reach each succeeding planet. The required outer planetary alignment occurs once every 176 years, whereas the Magellan mission to Venus could be launched in any year.

VOYAGER's first stop was at Jupiter with Voyager 1 and 2 arriving on March 5th and July 9th, 1979 respectively. Jupiter, the giant of all the planets, is so large that 1300 Earths could fit within it. Jupiter is mostly made of hydrogen and helium in liquid or gaseous states. Huge storms rage in its atmosphere. One, the Great Red Spot, is a storm about three times the size of Earth that has been viewed from Earth for over 350 years. A surprise feature discovered by Voyager was the ring that encircles Jupiter. It is made up of very fine particles, such that it was visible only when the spacecraft went behind Jupiter and looked back as the sunlight was forward-scattered off of the fine material. Besides the one new ring, three new satellites were discovered at Jupiter.

Another surprise was the discovery of volcanoes or geysers on the moon Io. Nine active volcanoes were seen by Voyager: One was imaged showing sulphur material being spewed 210 kilometers above the surface - the fallout from this volcano could cover an area 1.5 times the size of Japan. The sulphur deposits provide the vivid golden colors seen on the surface of Io. It is believed that Io undergoes tidal heating caused by the effect of Jupiter's gravity pulling one direction and the other Galilean moons (Ganymede, Callisto, and Europa) pulling another. This action provides the energy for heating the molten sulphur under Io's surface which eventually spews forth from the volcanoes.

Voyager's next stop was at Saturn with Voyager 1 and2arriving on November 12th 1980 and August 25th, 1981 respectively. The Voyager 1 trajectory at Saturn took it on a close flyby of the moon Titan, a prime target for the scientists, and then behind the rings of Saturn. This caused the trajectory to be deflected upward out of the ecliptic plane at abouta 35-degree angle, such that no further planetary encounters were possible for Voyager 1.

Saturnis also huge compared to Earth, about 850 times larger involute. Its atmosphere is not as dramatic to view as Jupiter's because of a high haze layer that enshrouds the planet. Its atmosphere also is composed of mostly hydrogen and helium.

But when you look at Saturn, your attention is immediately drawn to the rings. The ring material is mostly water ice ranging in size from a grain of sugar to the size of a house. When viewed in false-colored images, the complexity of the ring structure stands out: Hundreds of ripples can be seen in the ring system, caused by the gravity pull of Saturn and its moons on the ring material. Three new rings and six new satellites were discovered at Saturn.

As mentioned earlier, Saturn's largest moon, Titan, was a high-priority target for the scientists. It was thought that possibly lakes or oceans of liquid ethane would be seen on the surface. Imagine the disappointment when the images of Titan looked like Los Angeles on a smoggy day. Titan has an atmosphere, mostly of nitrogen, 10 times as thick as Earth's, so the surface could not be seen from Voyager images. Methane vapor may in fact act much like water vapor does on Earth including the formation of methane lakes on Titan.

Voyager 2's next stop was at Uranus, arriving on January 24th, 1986. Since Voyager 1 was successful in gathering data at Titan, Voyager 2 was allowed to go on to Uranus and then to Neptune, completing the tour of the giant outer planets.

Uranus turned out to be a disappointment as far as viewing the atmosphere was concerned. It resembled a blue cue ball, devoid of the spectacular atmospheric features seen on Jupiter and Saturn. The color is caused by methane in the atmosphere which absorbs in the red end of the spectrum, making sunlight that is scattered back from the planet look blue-green. The rotation axis of Uranus is tipped 98 degrees, so that as Voyager approached the planet, the south pole was facing the spacecraft and the rings around the equator or gave the image of a large target with Uranus as the bull's eye. Two new rings and 10 new satellites were discovered at Uranus.

But one of the surprises of Uranus was that, unlike any other planet visited before, its magnetic field was titled 60 degrees from the rotation axis of the planet. Also, the center of the magnetic field was not at the center of Uranus; it was offset by three-fourths of the planets' radius.

The major surprise attraction at Uranus was the moon Miranda. The surface of Miranda is marked by crisscrossed grooves, with parallel fault systems encircling even more complex grooved terrain. Huge canyons slice this tiny moon's surface. One cliff, over 19 kilometers high, caused one scientist to calculate that if you stepped off of it, it would take you nine minutes to hit the bottom.

Voyager 2's last stop was at Neptune, arriving on August 24, 1989. Neptune, like Uranus, has enough methane in its atmosphere to also absorb the red from the sunlight and reflect a bluish-green color. But unlike Uranus, Neptune's atmosphere offered several features for the scientist to examine. One was the Great Dark Spot, a hurricane-like storm about the size of Earth, as large relative to Neptune as the Great Red Spot is to Jupiter. Also seen was a smaller dark spot with a white cloud in its center (Dark Spot 2), and a triangular-shaped cloud named "Scooter," because it moved around Neptune faster than the other features. The high-altitude clouds next to the Great Dark Spot are believed to be methane-ice clouds as is the cloud in the center of Dark Spot 2.

Neptune had wind speeds measured at 1125 kilometers per hour at the equator, blowing in a westerly direction, which is opposite to the direction of rotation of Neptune. By comparison, Jupiter's winds at the equator were in an easterly direction at about 400 kilometers per hour, Saturn had wind speeds of 1770 kilometers per hour also easterly at the equator, and at Uranus, easterly winds of about 560 kilometers per hour were recorded. Some winds near the Great Dark Spot of Neptune were clocked at about 2410 kilometers per hour, making Neptune the windiest of the planets.

Then an additional surprise at Neptune was that it also had a magnetic field that is tipped at 47 degrees to its rotation axis showing that Uranus was not such an accident after all. Likewise, Neptune was also found to have a true ring system like the other three planetary giants. Five rings and eight new satellites were discovered at Neptune.

Using radio signal tracking, the gravity field of a planet can be calculated, and hence, its density. This was done at each Voyager encounter and provided the following results, 1.0 grams per cubic centimeter being the density of water: The density of Jupiter is 1.33, Saturn 0.69, Uranus 1.27, and Neptune 1.64. Neptune, then, is more dense than the other large gaseous planets; Saturn could actually float" in water. The abundance of rocky material in the interior of Neptune may be a clue to the large amount of heat generated within Neptune, possibly due to radioactivity of the molten rock.

Voyager was able to fly to within 25,000 miles of Neptune's retrograde orbiting moon, Titan, returning spectacular images of the cold, frozen surface. The surface temperature was measured at 38 degrees Kelvin or -237 degrees Centigrade. Various different types of terrain can be seen. in the southern hemisphere, a methane-ice cap covers most of the polar region. At the edge of the polar ice cap, what appears to be a fracture or fault line is visible. The scientists believe that when Triton was formed, the surface froze first, and then the interior, containing water ice, froze and expanded, breaking the surface. Above the ice cap, the surface looks bluish, caused by nitrogen ice. In a nearby region there is a very smooth terrain with features that look like the volcanic calderas or craters that we have on Earth. Several geysers were spotted in the images, probably spewing nitrogen along with dust particles into the atmosphere.

MAGELLAN's only planetary stop was insertion into orbit around Venus on August 10, 1990, Radar mapping of the Venusian surface commenced on September 15, 1992. Since then, 99 percent of the surface has been mapped with resolutions on the order of 120 meters. In fact, Magellan has generated more digital planetary image data than all previous missions. Other data types acquired include altimetry, radiometry, and gravity data sets.

Magellan has shown that Venus has tectonic and volcanic styles that are both the same and different from those on Earth. On a global scale, Venus and Earth are different, since Venus does not have the plate tectonics that characterizes Earth. On a sub-global scale, Venus has rift valleys like those on Earth. The most common tectonic features on Venus arise from mantle plumes which occur infrequently on Earth. Venus has thousands of volcanic constructs and flows. Many of these Venusian volcanic features are similar to those on Earth and Io. Indeed, lava may be likened to water on Earth due to the discovery of a flow several thousand kilometers long.

Magellan discovered that Venus has wind-formed features such as dunes and "wind-streaks" behind surface obstacles. These wind-related features indicate that the Venusian atmosphere has a Hadley (which was not seen by Voyager on the outer planets) type of circulation where hot gases rise at the equator and travel at high altitude toward the poles. At the poles, these gases cool, fall and return to the surface. The atmospheric gases then travel along the surface, returning to the equatorial regions of Venus where these once again are heated and start the atmospheric cycle again.

Magellan also revealed over 800 impact craters. The number and distribution of these craters on the surface likely indicate that most of the Venusian surface is about 500 million years old. This is about 12 times older than the average age of the Earth's surface and 10 times younger than the surfaces on Mercury, Mars and the Moon. Larger Venusian craters with diameters from about 60 kilometers up to about 200 kilometers tend to have double crater rims like larger impact craters on other surfaces in the inner solar system. Craters with diameters of a few tens of kilometers tend to have characteristics that are like those of similar sizes on Mars, Mercury and the Moon; however, the thick Venusian atmosphere disrupts the kilometer-sized impactors resulting in smaller multiple impact craters as well as circular surface shock features.

But the Odyssey of Voyager and Magellan takes a final divergence. Although there would have been no Magellan without Voyager since Magellan was partially constructed from leftover Voyager spare parts, the Magellan mission will end in 1993 after completion of the current 243-day gravity data cycle. Meanwhile, the Voyager Odyssey into interstellar space may continue for another 25 years, well into the 21st century.

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